The effect of safety factor profile on transport in steady-state, high-performance scenarios

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Abstract

An analysis of the dependence of transport on the safety factor profile in high-performance, steady-state scenario discharges is presented. This is based on experimental scans of q_{95} and $q_{\min}$ taken with fixed β_N, toroidal field, double-null plasma shape, divertor pumping, and electron cyclotron current drive (ECCD) input. The temperature and thermal diffusivity profiles were found to vary considerably with the q-profile, and these variations were significantly different for electrons and ions. With fixed q_{95}, both temperature profiles increase and broaden as $q_{\min}$ is increased and the magnetic shear becomes low or negative in the inner half radius, but these temperature profile changes are stronger for the electrons. Power balance calculations show the peak in the ion thermal diffusivity (χ_i) at $\rho = 0.6 - 0.8$ increases with q_{95} or $q_{\min}$. In contrast, the peak in the electron diffusivity (χ_e) decreases as $q_{\min}$ is raised from ~ 1 to 1.5, and it is insensitive to q_{95}. This is important for fully non-inductive scenario development because it demonstrates that elevated $q_{\min}$ and weak or reversed shear allows larger electron temperature gradients and therefore increased bootstrap current density to exist at $\rho = 0.6 - 0.8$. Chord-averaged measurements of long wavelength density fluctuation amplitudes $(\tilde{n})$ are shown, and these have roughly the same dependence on q-profile as χ_i. This data set provides an opportunity for testing whether theory based transport models can provide insight into the underlying transport physics of high performance scenarios and if they can reproduce observed experimental trends. To this end we applied the TGLF code to calculate the linear stability of drift waves and found that the resulting variation of growth rates with q-profile are mostly inconsistent with the observed trends of χ_i, χ_e and $\tilde{n}$ with q-profile. TGLF simulations of the temperature profiles consistent with heating sources also have mixed agreement with the measured profiles, such that the simulated electron and ion heat flux in low $q_{\min}$ discharges are too low and heat fluxes in high $q_{\min}$ discharges are too high.